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Indian Standard

GEOMETRICAL PRODUCT SPECIFICATIONS (GPS) — ACCEPTANCE AND REVERIFICATION TESTS FOR COORDINATE MEASURING MACHINES (CMM)

PART 3 CMMs WITH THE AXIS OF A ROTARY TABLE AS THE FOURTH AXIS

ICS 17.040.30

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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NATIONAL FOREWORD

This Indian Standard (Part 3) which is identical with ISO 10360-3 : 2000 'Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 3 : CMMs with the axis of a rotary table as the fourth axis' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Engineering Metrology Sectional Committee and approval of the Medical Instruments, General and Production Engineering Division Council.

Coordinate measuring machines (CMMs) are most modern method of dimensional inspection. With the advent of numerically controlled machine tools, demand grew for a means to support this equipment with faster first piece inspection and in many cases 100 percent inspection. To fill this gap CMMs were developed by modifying precision layout machines.

The acceptance test and reverification test of this part of ISO 10360 are applicable to CMMs which use a rotary table for the orientation of a workpiece being measured.

The tests specified in this part of ISO 10360 are performed in addition to the size measuring tests according to ISO 10360-2, which are conducted with the rotary table stationary. They are designed to detect the system measuring errors relative to an axis system fixed to the rotary table. It is normally not useful to isolate the rotary table errors from other sources of machine error.

The text of the ISO Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain terminology and conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker in the International Standard, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 10360-1 : 2000 Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 1 : Vocabulary	IS 15635 (Part 1) : 2005 Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) : Part 1 Vocabulary	Identical
ISO 14253-1 : 1998 Geometrical Product Specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 1 : Decision rules for proving conformance or non-conformance with specifications	IS 15371 (Part 1) : 2003 Geometrical Product Specifications (GPS) — Inspection by measurement of workpieces and measuring equipment: Part 1 Decision rules for proving conformance or non-conformance with specifications	do

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Indian Standard

GEOMETRICAL PRODUCT SPECIFICATIONS (GPS) — ACCEPTANCE AND REVERIFICATION TESTS FOR COORDINATE MEASURING MACHINES (CMM)

PART 3 CMMs WITH THE AXIS OF A ROTARY TABLE AS THE FOURTH AXIS

1 Scope

This part of ISO 10360 specifies the acceptance test which verifies that the performance of four-axis coordinate measuring machines (CMM) is in accordance with that stated by the manufacturer. It also specifies the reverification test, which enables the user to reverify the performance of a four-axis CMM periodically.

The acceptance test and reverification test described in this part of ISO 10360 are applicable only to four-axis machines with three axes for measuring workpiece coordinates, plus a rotary table for orienting the workpiece.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 10360. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 10360 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 10360-1:—[1], *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 1: Vocabulary.*

ISO 14253-1:1998, *Geometrical Product Specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 1: Decision rules for proving conformance or non-conformance with specifications.*

International Vocabulary of Basic and General Terms in Metrology (VIM). BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 2nd edition, 1993.

3 Terms and definitions

For the purposes of this part of ISO 10360, the terms and definitions given in ISO 10360-1, ISO 14253-1 and VIM apply.

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[1] To be published.

4 Requirements for metrological characteristics

4.1 Error of indication

The errors of indication, FR, FT, FA, as defined in ISO 10360-1, for the three four-axis errors shall not exceed the maximum permissible errors, MPE_{FR}, MPE_{FT}, MPE_{FA}, as defined in ISO 10360-1, as stated by:

— the manufacturer, in case of acceptance tests;

— the user, in case of reverification tests.

The errors of indication (FR, FT, FA) and the maximum permissible errors (MPE_{FR}, MPE_{FT}, MPE_{FA}) are expressed in micrometres.

4.2 Environmental conditions

Limits to be respected for permissible environmental conditions such as temperature conditions, air humidity and vibration at the site of installation that influence the measurements shall be specified by:

— the manufacturer, in case of acceptance tests;

— the user, in case of reverification tests.

In both cases, the user is free to choose the conditions within the specified limits.

4.3 Rotary table

The maximum permissible errors (MPE_{FR}, MPE_{FT}, MPE_{FA}) apply for any permitted loading, location and orientation of the rotary table on the CMM and for any locations of the test spheres on the rotary table within specified limits.

4.4 Stylus system

Limits to be respected for the stylus system configuration, to which the stated values of MPE_{FR}, MPE_{FT}, MPE_{FA} apply, shall be specified by:

— the manufacturer, in case of acceptance tests;

— the user, in case of reverification tests.

In both cases, the user is free to choose the stylus system configuration within the specified limits.

The form deviation of the stylus tip will influence the measurement results and shall be considered when proving conformance or non-conformance with specifications.

4.5 Operating conditions

The CMM shall be operated using the procedures given in the manufacturer's operating manual when conducting the tests given in clause 5. Specific areas in this manual to be adhered to are, for example:

a) machine start up/warm up cycles;

b) stylus system configuration;

c) cleaning procedures for stylus tip and reference sphere;

d) probing system qualification;

e) rotary table set-up and qualification.

NOTE The stylus tip and the reference sphere should be cleaned before the probing system qualification so as to leave no residual film which could affect the measuring or test result.

5 Acceptance test and reverification test

5.1 Principles

The principle of the assessment method is to establish whether the CMM is capable of measuring within the stated maximum permissible errors ($\mathrm{MPE}_{\mathrm{FR}}$, $\mathrm{MPE}_{\mathrm{FT}}$, $\mathrm{MPE}_{\mathrm{FA}}$) by determining the variation of the measured coordinates of the centres of two test spheres mounted on the rotary table.

It is noted that on a perfect four-axis CMM, the location of the measured centres of the test spheres would remain fixed in the workpiece coordinate system while the table is rotated.

Each test sphere centre is determined in three directions: radial, tangential and axial. The position of each test sphere centre is represented in the workpiece coordinate system on a rotary table.

The centre of each test sphere, mounted on a rotary table, is measured in a series of measurements with different angular positions of the rotary table.

The errors of indication (FR, FT, FA) are calculated separately for each test sphere as the range between the maximum and minimum measurement results for each of the three directions.

In the following:

— acceptance tests are executed according to the manufacturer's specifications and procedures;

— reverification tests are executed according to the user's specifications and the manufacturer's procedures.

5.2 Measuring equipment

5.2.1 Two test spheres (A and B), with diameters no less than 10 mm and no greater than 30 mm and with certified form.

The diameters of the two test spheres, used in these tests as the corresponding input quantities, need not be calibrated since only the centres of the test spheres are used to determine the three four-axis errors. The form of the test spheres must be calibrated since the form deviations influence the test results and shall be taken into account when proving conformance or non-conformance with specifications.

The mounting of the test spheres should be sufficiently rigid to avoid errors due to bending especially when the axis of the rotary table is horizontal.

5.3 Procedure

Position the test sphere A on the rotary table as close as possible to the rotary table surface at a radius r, in accordance with Table 1. Position the test sphere B approximately at the same radius, r, and approximately diametrically opposite the test sphere A at a height, Δh (see Table 1 and Figure 1).

Define a Cartesian workpiece coordinate system on the rotary table (see Figure 1) conforming to the following conditions:

a) the centre of test sphere B (farthest from the table surface) establishes the origin;

b) the primary axis which defines the axial direction shall be parallel to the axis of the rotary table;

c) the secondary axis which defines the radial direction shall lie in a plane that contains the primary axis and the centre of test sphere A.

NOTE 1 The tertiary axis defines the tangential direction.

Once the workpiece coordinate system is established begin the test by measuring test sphere B in its original position (position 0). The user can choose any angular position other than the zero reading of the rotary table for position 0 in Table 2.

Then the rotary table is rotated through a series of seven angular positions, and the position of the test sphere A is measured in each position. It is recommended that the positions of the seven measurements extend at least 720° from the starting position. Then the rotary table is rotated in the opposite direction to seven angular positions and the test sphere A is measured in each position. When the rotary table is returned to its starting position both test spheres should then be measured as position 14.

The rotary table is then rotated in the same direction to seven different angular positions and then rotated in the opposite direction to seven angular positions. The test sphere B is measured at each position. When the rotary table is returned to its original position both test spheres should be measured as position 28 (see Table 2).

NOTE 2 The heights and radii according to Table 1 are specified to facilitate comparisons between CMMs.

NOTE 3 The values of 200 mm transform each second of arc of angular error to approximately one micrometre of linear error. For aid in comparison of machines with differing measuring volumes, and in matching machine capability to workpiece tolerance requirements for large parts (i.e. parts larger than the table size), the errors resulting from the test procedures above are approximately proportional to the height and distance used.

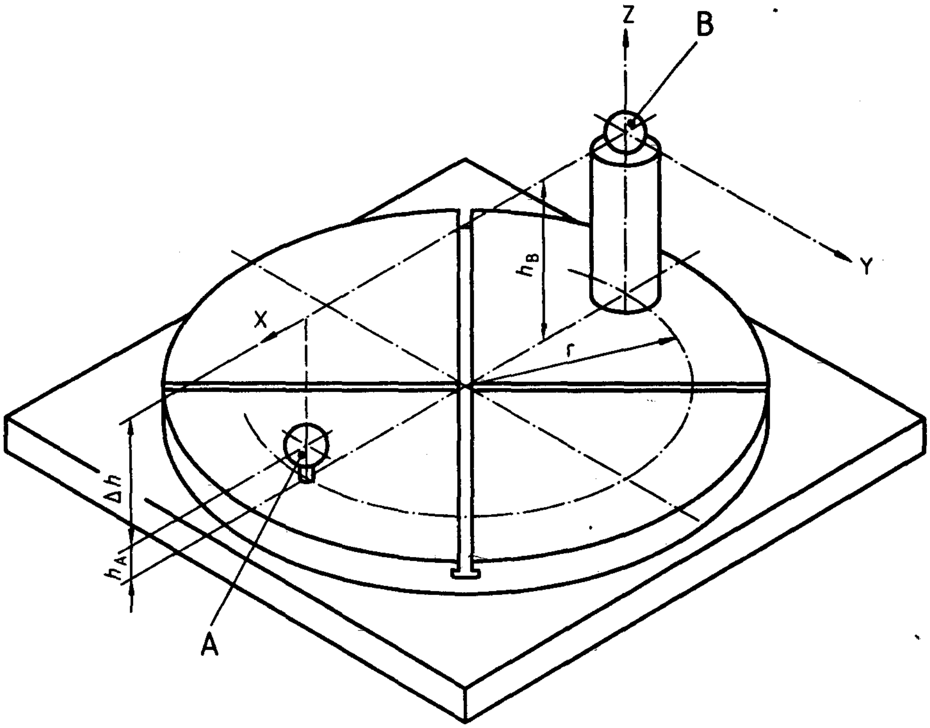
NOTE 4 The user may choose any loading, location and orientation of the rotary table on the CMM within the limits specified by the manufacturer. The manufacturer and user may agree to additional test(s) using different test sphere location(s), if required.

NOTE 5 Some CMMs use the rotary table as a means of extending the measuring volume. On such CMMs, the test sphere may only be accessible to the probing system over an arc of rotation of the table which is less than 360°. On such machines the starting angular position of the rotary table must be such that the positions of both test spheres can be measured.

Table 1 — Location of the test spheres on the rotary table

Combination No.	Height difference Δh mm	Radius r mm
1	200	200
2	400	200
3	400	400
4	800	400
5	800	800

NOTE Default values — one of the above combinations which must be specified by the manufacturer. Other values may be used by agreement between the manufacturer and the user.



NOTE The X, Y and Z designations in this figure are used to illustrate directions with respect to the rotary table and do not necessarily represent machine axis designations.

Figure 1 — Test sphere positions on the rotary table for the acceptance test and reverification test

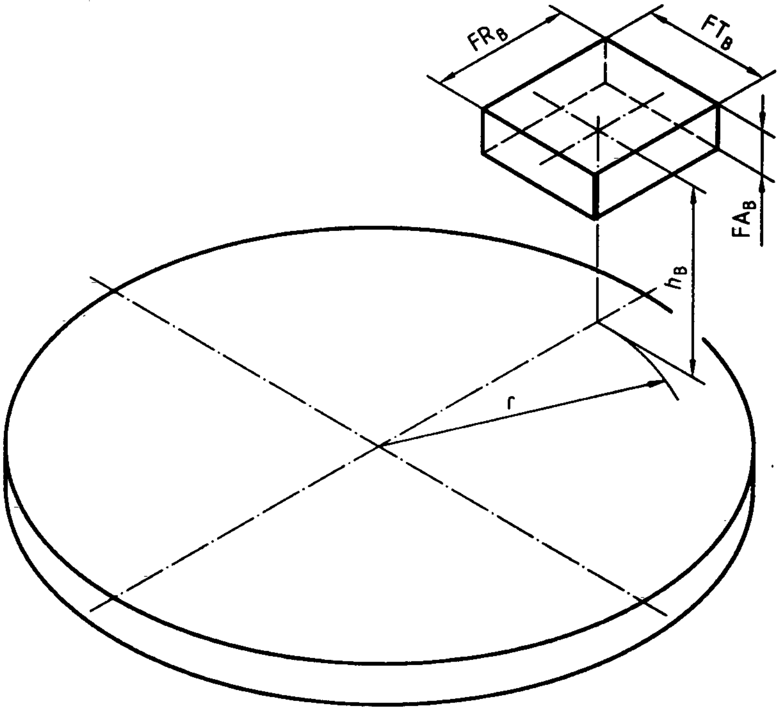
5.4 Obtainment of test results

Using measurements from positions 0 to 28 (designated X_A, Y_A, Z_A coordinates for test sphere A and X_B, Y_B, Z_B coordinates for test sphere B), compute the three four-axis errors (FR, FT, FA) as the peak-to-peak variation of each of the radial, tangential and axial coordinates of both the test sphere centres (see Table 2 and Figure 2).

NOTE 1 X_A and X_B are the radial components of the centres of the test spheres A and B to be used for the calculation of the radial four-axis error FR_A and FR_B.

NOTE 2 Y_A and Y_B are the tangential components of the centres of the test spheres A and B to be used for the calculation of the tangential four-axis error FT_A and FT_B.

NOTE 3 Z_A and Z_B are the axial components of the centres of the test spheres A and B to be used for the calculation of the axial four-axis error FA_A and FA_B.



NOTE 1 r is the radius of test sphere B from the axis of the rotary table.

NOTE 2 h_B is the height of the centre of test sphere B from the workpiece clamping surface of the rotary table.

NOTE 3 The position of test sphere A is not indicated for reasons of clarity.

Figure 2 — Schematic representation of the volume generated by the three four-axis errors (FR$_B$, FT$_B$, FA$_B$) for the acceptance test and reverification test for a CMM with the axis of a rotary table as the fourth axis

Table 2 — Default nominal angular positions for rotary table test

Position No.	Angular position degrees		Measured coordinates for					
			Test sphere A			Test sphere B		
	W_1	W_2	X_A	Y_A	Z_A	X_B	Y_B	Z_B
0	0	0	X_{A0}	$Y_{A0} = 0$	Z_{A0}	$X_{B0} = 0$	$Y_{B0} = 0$	$Z_{B0} = 0$
1	75	135	X_{A1}	Y_{A1}	Z_{A1}	—	—	—
2	125	225	X_{A2}	Y_{A2}	Z_{A2}	—	—	—
3	175	315	X_{A3}	Y_{A3}	Z_{A3}	—	—	—
4	385	405	X_{A4}	Y_{A4}	Z_{A4}	—	—	—
5	410	540	X_{A5}	Y_{A5}	Z_{A5}	—	—	—
6	510	630	X_{A6}	Y_{A6}	Z_{A6}	—	—	—
7	820	810	X_{A7}	Y_{A7}	Z_{A7}	—	—	—
8	510	630	X_{A8}	Y_{A8}	Z_{A8}	—	—	—
9	410	540	X_{A9}	Y_{A9}	Z_{A9}	—	—	—
10	385	405	X_{A10}	Y_{A10}	Z_{A10}	—	—	—
11	175	315	X_{A11}	Y_{A11}	Z_{A11}	—	—	—
12	125	225	X_{A12}	Y_{A12}	Z_{A12}	—	—	—
13	75	135	X_{A13}	Y_{A13}	Z_{A13}	—	—	—
14	0	0	X_{A14}	Y_{A14}	Z_{A14}	X_{B14}	Y_{B14}	Z_{B14}
15	− 75	− 135	—	—	—	X_{B15}	Y_{B15}	Z_{B15}
16	− 125	− 225	—	—	—	X_{B16}	Y_{B16}	Z_{B16}
17	− 175	− 315	—	—	—	X_{B17}	Y_{B17}	Z_{B17}
18	− 385	− 405	—	—	—	X_{B18}	Y_{B18}	Z_{B18}
19	− 410	− 540	—	—	—	X_{B19}	Y_{B19}	Z_{B19}
20	− 510	− 630	—	—	—	X_{B20}	Y_{B20}	Z_{B20}
21	− 820	− 810	—	—	—	X_{B21}	Y_{B21}	Z_{B21}
22	− 510	− 630	—	—	—	X_{B22}	Y_{B22}	Z_{B22}
23	− 410	− 540	—	—	—	X_{B23}	Y_{B23}	Z_{B23}
24	− 385	− 405	—	—	—	X_{B24}	Y_{B24}	Z_{B24}
25	− 175	− 315	—	—	—	X_{B25}	Y_{B25}	Z_{B25}
26	− 125	− 225	—	—	—	X_{B26}	Y_{B26}	Z_{B26}
27	− 75	− 135	—	—	—	X_{B27}	Y_{B27}	Z_{B27}
28	0	0	X_{A28}	Y_{A28}	Z_{A28}	X_{B28}	Y_{B28}	Z_{B28}
Four-axis errors			FR_A	FT_A	FA_A	FR_B	FT_B	FA_B

NOTE Angular positions W_1 apply to CMMs with partial coverage of the rotary table. Angular positions W_2 apply to CMMs with full coverage of the rotary table. Only one of these columns applies to a specific machine being tested. In this table a dash (—) means that no measurement is made of the location of that test sphere in that angular position. (See note 5, 5.3.)

6 Compliance with specifications

6.1 Acceptance test

The performance of the CMM with the axis of a rotary table as the fourth axis is verified if none of the four-axis errors (FR_A, FT_A, FA_A, FR_B, FT_B, FA_B) are greater than the three maximum permissible four-axis errors (MPE_{FR}, MPE_{FT}, MPE_{FA}) as specified by the manufacturer, taking into account the uncertainty of measurement according to ISO 14253-1.

6.2 Reverification test

The performance of the CMM with the axis of a rotary table as the fourth axis is verified if none of the four-axis errors (FR_A, FT_A, FA_A, FR_B, FT_B, FA_B) are greater than the three maximum permissible four-axis errors (MPE_{FR}, MPE_{FT}, MPE_{FA}) as specified by the user. If compliance with specification shall be proved, the uncertainty of measurement shall be taken into account according to ISO 14253-1.

7 Applications

7.1 Acceptance test

In a contractual situation between a supplier and a customer such as described in

- a purchasing contract,
- a maintenance contract,
- a repair contract,
- a renovation contract,
- an upgrading contract, etc.,

the acceptance test described in this part of ISO 10360 can be used as a test to verify the performance of a CMM with the axis of a rotary table as the fourth axis in accordance with the specified maximum permissible errors MPE_{FR}, MPE_{FT} and MPE_{FA} as agreed upon by the supplier and the customer.

If the supplier does not specify any limitations, the three stated maximum permissible errors MPE_{FR}, MPE_{FT} and MPE_{FA} apply for any loading, location and orientation of the rotary table on the CMM.

7.2 Reverification test

In an organization's internal quality assurance system, the reverification test described in this part of ISO 10360 can be used as a test to verify the performance of a CMM with the axis of a rotary table as the fourth axis in accordance with the specified maximum permissible errors MPE_{FR}, MPE_{FT} and MPE_{FA} as stated by the user with possible detailed limitations applied.

7.3 Interim check

In an organization's internal quality assurance system, a reduced reverification test may be used periodically to demonstrate the probability that the CMM will conform with specified requirements regarding the three maximum permissible errors MPE_{FR}, MPE_{FT} and MPE_{FA}.

The extent of the reverification test as described in this part of ISO 10360 may be reduced in the following areas: number of test spheres, angular positions and number of measurements being performed.

Annex A
(informative)

Interim check

If a rotary table is fixed to the CMM, the test described in clause 5 may be sufficient to quantify all errors related to all machine axes. It is not required to re-check all linear axes since all axes must be in "good working order" for the result of FR, FT and FA to conform with the specifications.

Annex B
(informative)

Relation to the GPS matrix model

For full details about the GPS matrix model, see ISO/TR 14638.

B.1 Information about this part of ISO 10360 and its use

This part of ISO 10360 specifies the verification methods for proving conformance of coordinate measuring machines with the specified MPEs. The tests of this part of ISO 10360 are:

- applicable to a four-axis coordinate measuring machine with three axes for measuring workpiece coordinates, plus a rotary table for orienting the workpiece;
- designed to detect the system measuring errors relative to an axis system fixed to the rotary table;
- performed in addition to the size measuring tests according to ISO 10360-2, which are conducted with the rotary table stationary.

B.2 Position in the GPS matrix model

This part of ISO 10360 is a general GPS standard, which influences the chain link 5 of the chains of standards on size, distance, radius, angle, form, orientation, location, run-out and datums in the general GPS matrix, as graphically illustrated in Figure B.1.

Fundamental GPS standards

Global GPS standards

General GPS standards						
Chain link number	**1**	**2**	**3**	**4**	**5**	**6**
Size					▨	
Distance					▨	
Radius					▨	
Angle					▨	
Form of line independent of datum					▨	
Form of line dependent on datum					▨	
Form of surface independent of datum					▨	
Form of surface dependent on datum					▨	
Orientation					▨	
Location					▨	
Circular run-out					▨	
Total run-out					▨	
Datums					▨	
Roughness profile						
Waviness profile						
Primary profile						
Surface imperfections						
Edges						

Figure B.1

B.3 Related standards

The related standards are those of the chains of standards indicated in Figure B.1.

Bibliography

[1] ISO 10360-2:—[2], *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 2: CMMs used for measuring linear dimensions.*

[2] ISO/TR 14638:1995, *Geometrical Product Specifications (GPS) — Masterplan.*

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[2] To be published. (Revision of ISO 10360-2)

(*Continued from second cover*)

The technical committee reviewed the provisions of International Vocabulary of Basic and General Terms in General Metrology (VIM) referred in this adopted standard and decided that it is acceptable for use in conjunction with this standard.

ISO 10360 consists of the following other parts:

Part 1	Vocabulary
Part 2	CMMs used for measuring size
Part 4	CMMs used in scanning measuring mode
Part 5	CMMs using multiple-stylus probing systems
Part 6	Estimation of errors in computing Gaussian associated features

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards: Monthly Additions'.

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Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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